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The influence of national temperature fluctuations on opinions about climate change in the U.S. since 1990

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Abstract Public opinion in the United States about human-caused climate change has varied over the past 20 years, despite an increasing consensus about the issue in the expert community. Attitudes about climate change have been attributed to a number of factors including personal values, political ideology, the media environment and personal experience. Recent studies have found evidence that the temperature can influence one's opinion about climate change and willingness to change behaviour and/or support climate policy. Although there is some evidence that individual cool or warm years have influenced large-scale opinion about climate change, the extent to which temperature can explain the past variability in public opinion and public discourse about climate change at the national level is not known. Here we isolate the relationship between opinion about climate change and temperature at the national scale, using data from opinion polls, a discourse analysis of opinion articles from five major daily newspapers, and a national air temperature database. The fraction of respondents to national polls who express "belief in" or "worry about" climate change is found to be significantly correlated to U.S. mean temperature anomalies over the previous 3–12 months. In addition, the fraction of editorial and opinion articles which "agree" with the expert consensus on climate change is also found to be significantly correlated to U.S. mean temperature anomalies at seasonal and annual scales. These results suggest that a fraction of the past variance in American views about climate change could potentially be explained by climate variability.

1 Introduction

Over the past 20 years, public attitudes about the evidence for human-caused climate change and action to address climate change have varied (Nisbet and Meyers 2007). Individual attitudes about climate change are thought to be influenced by many factors including personal values and political ideology (McCright and Dunlap 2003, 2010, 2011; Whitmarsh 2011), current

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events (Nisbet and Meyers 2007), media coverage (Boykoff and Boykoff 2004), organized climate "skepticism" (Oreskes and Conway 2010), political trends (Dunlap and McCright 2008), cultural history (Donner 2007, 2011) and risk perception (Weber 2006); see Marquart-Pyatt et al. (2011) for a review. Recently, psychological research has also examined the role of the physical environment on attitudes about climate change. Experimental and local-scale studies have reported that the weather, or the perceived weather, can influence one's opinion on climate change and willingness to change behaviour or support climate policy (Zahran et al. 2006; Krosnick et al. 2006; Brody et al. 2008; Semenza et al. 2008; Hamilton and Keim 2009; Freudenberg and Muselli 2010; Joireman et al. 2010; Li et al. 2011).

The drivers of individual attitudes about climate change may integrate at the national scale to influence opinion polls and the national conversation about climate change. The weather is an ideal example. If much of the country experiences a cold (or warm) year, a national opinion poll may find some decrease (increase) in concern about climate change because the respondents' individual experiences with the weather, or exposure to media coverage about the weather, influenced their attitudes. Although past studies have suggested that a particular anomalous seasons, like the hot summer of 1988, influenced U.S. public opinion or media coverage of climate change (Shanahan and Good 2000; Zehr 2000; Boykoff and Boykoff 2004; Krosnick et al. 2006; Freudenberg and Muselli 2010), there has not as of yet been a comprehensive analysis of the relationship between climate variability and the variations in public and media opinion over time. There is some evidence that economic factors, as well as weather, influence opinion poll data on climate change (e.g. Scruggs and Benegal 2012), but such analysis is limited by the length of the polling time series.

In this paper, we attempt to isolate the possible relationship between large-scale climate variability and national opinion about climate change using 1990–2010 data from national public opinion polls and a discourse analysis of opinion articles from major U.S. newspapers. First, we evaluate the relationship between national-mean temperature and the "belief in" and "worry about" climate change expressed in national opinion polls. Second, we supplement this initial analysis by evaluating the relationship between temperature variability and attitudes about climate change expressed in editorial and opinion articles published in five newspapers. The opinion article analysis, which features a longer time series, provides an additional and more robust test of whether climate variability influences the national conversation about climate change. Together, the results provide evidence that climate variability likely explains some of the past variability in U.S. public opinion about climate change.

2 Methods

This section describes the data sources and the methods used to gather, code and analyse the data. The period of analysis was restricted to 1990 to 2010 due to data availability.

2.1 Public opinion data

Four U.S. agencies (Gallup, Harris, the ABC/Woods Institute and the Pew Center for the People and the Press) have polled public opinion on climate change using consistent questions over time (Table 1). Although each agency employs different language to gauge public opinion about climate change, versions of the following two general questions were common:

1. Do you believe that the earth is warming (or in “global warming”)?
2. How much do you worry about global warming or climate change?

The primary analysis employed the Gallup data, which had the most data for question #1 (11 data points from 1997 to 2010) and question #2 (16 data points from 1989 to 2010). In order to test whether the results are robust across different polls, a secondary analysis was conducted using a composite of data from all agencies, for which records are much shorter (Table 1). Raw poll data from different agencies are not directly comparable (e.g. Schuldt et al. 2011), so anomalies in polling responses were calculated and used to construct a composite result for each question. This method has been employed in other studies (e.g. Brulle et al. 2012). The composite analysis was restricted to the period since 1997 due to data availability.

With each poll, the responses to a question in a given year (a_k) were converted to anomalies $\left(a'_k\right)$ from the long-term average response for that question from that polling agency.

$$a'_k(m) = a_k(m) - \sum_{i=1}^{n} a_i(m), \tag{1}$$

where k = year and m = response (e.g. yes)

For the composite analysis, mean response anomalies $\left(\alpha'_k\right)$ were computed using the response anomalies from the different polls for that question in that year:

$$\propto'_k (m) = \overline{a'_k(m) + b'_k(m) + c'_k(m)}, \tag{2}$$

where a, b, c represent different polls

Table 1 Questions from the four chosen polls organized by representative questions

1. Do you believe that the earth is warming?		Years of data
Gallup	Which of the following statements reflects your view of when the effects of global warming will begin to happen – they have already begun, they will start within a few years, they will start within lifetime, they will not happen in lifetime but will affect future generations, or they will never happen?	11
ABC	Do you think global warming has probably been happening, or do you think it probably has not been happening?	7
Pew	From what you’ve read and heard, is there solid evidence that the average temperature on earth has been getting warmer over the past few decades, or not?	6
Harris	Do you believe the theory that increased carbon dioxide and other gases released into the atmosphere will, if unchecked lead to global warming and an increase in average temperatures, or not?	6
2. How much do you worry about global warming?		
Gallup	How much do you worry about the Greenhouse Effect, or Global Warming - Great Deal, Fair Amount, Only a Little, or Not at all?	16
ABC	How important is the issue of global warming to you personally - extremely important, very important, somewhat important, not too important, or not at all important?	7
Pew	In your view, is global warming a very serious problem, somewhat serious, not too serious, or not a problem?	6
Harris	Do you think that the possibility of global warming should be treated as a very serious problem, a somewhat serious problem or not a serious problem?	2

The mean error of the composite was assumed to be three percentage points. There was no statistically significant trend in any of the polling responses over the time period for which data on each question is available.

2.2 Opinion and editorial data

This analysis employs editorial and opinion articles (henceforth referred to as "opinion" articles) in order to focus on the key "claims makers" in the media that draw attention to and frame issues (Trumbo 1996). Opinion articles from five U.S. major daily newspapers (*New York Times, Wall Street Journal, Washington Post, USA Today* and *Houston Chronicle*) published between January 1, 1990 and January 1, 2010 were identified using the Lexis-Nexus media search engine. The first four newspapers were chosen because they are among the top ten in national circulation, have been used to represent the U.S. prestige press in previous studies of media coverage of climate change (Ungar 1992; Boykoff and Boykoff 2004; Antilla 2005; Russil and Nyssa 2009), and each had clearly distinguished opinion and editorial articles from other content in available archives. The *Houston Chronicle* was added for comparison because it serves the 4th largest city in the U.S. and has the greatest circulation in the Southwestern U.S. (Liu et al. 2008).

A two-person pilot analysis was conducted, using articles from 2009, to define criteria for coding articles. All editorials and articles classified as opinion which featured the term "climate change" and/or "global warming" were included in the initial analysis. Letters to the editor were included if they were authored by people claiming a professional affiliation (e.g. politicians, academics, private sector actors) because the goal was to evaluate the arguments put forth by opinion leaders. If the article did not express any particular attitude about the science of climate change, but did express an attitude about the importance of climate change, the article was included. Articles which included the search terms "climate change" or "global warming" but were devoted to other subjects were excluded.

After the pilot analysis, articles were read and coded by a single person based on the attitude towards the expert consensus that climate change is occurring and/or is a prominent public concern ("agree", "disagree" or "agnostic/unclear") following a coding matrix (Table 2). Combining "belief" in climate change and "concern" about climate change in a multi-level coding matrix was necessary in order to incorporate the opinion articles which express attitudes about different aspects of climate change in this study. The results were then used to calculate the percent of "agree" and "disagree" articles in a given season or year, henceforth referred to a percent agree and percent disagree, to control for changes in number of articles over time.

2.3 Climate data

Historical mean monthly temperatures for the continental U.S., as well as for the North-eastern U.S., were obtained from the National Climatic Data Centre. The data are based on spatial interpolation of station measurements in the U.S. Historical Climatology Network, and feature similar trend and inter-annual variability to that in the other large-scale temperature datasets (Menne et al. 2010). Monthly and seasonal temperature anomalies were computed for the 1990–2009 time period of the opinion analysis as the difference between that month's or that season's temperature and 1990–2009 mean for the month or season:

Table 2 Opinion article coding matrix

Category	Disagree	Agnostic/unclear	Agree
1. Reality of climate warming	The climate is not warming, or any warming is natural	The climate may be warming; human activity may play a role	The climate is warming due primarily to human activity
2. Perception of climate change	Climate change may occur, but it is not a threat	Climate change may be a threat, but how much of a threat is unknown	Climate change is a serious threat
3. Validity of climate science	Human-caused climate change has not proven by climate science	Human-caused climate change is real, but there is some disagreement among climate scientists.	Climate scientists have proven that human-caused climate change is real and progressing
4. Scientific justification for action	There is no scientific consensus that climate change is real; action should be postponed	Many climate scientists agree that climate change is occurring, but uncertainty poses an obstacle to action.	Climate scientists agree that climate change is occurring; immediate action is required to combat this threat

$$T'_{year}(month(s)) = T_{year}(month(s)) - \sum_{i=1990}^{2009} T_i(month(s)) \tag{3}$$

The relationship between the variability in the opinion (polling, newspaper) data and temperature anomalies (T′) was evaluated using standard linear regression analysis as well as z-tests for significant difference between sample means. For the Gallup analysis, polling responses were regressed against temperature anomalies with time lags of 0–12 months since the month of the poll in order to account for the possible time lag between weather experience and changes in opinion (T′ for the past X months is expressed as T'_x). For the composite analysis, the polling responses were regressed against T′ for 12 months preceding March, the first month of the year in which any of the polls were conducted.

The analysis of the newspaper data and the climate data was conducted at the annual scale and at the seasonal scale. The four seasons were set to the calendar year (winter = January, February, March), rather than the standard climate definition of the seasons (winter = December, January, February) to ease statistical comparison with the newspaper data. Monthly analysis is not presented because of the large number of months with no opinion articles.

3 Results

3.1 Polling question #1: belief in global warming

There was a significant positive relationship between temperature over the previous year and the belief in global warming in the Gallup data and in the secondary composite poll data (Fig. 1). In the Gallup data, the fraction of respondents who believe warming has already begun or will begin within a few years is strongly correlated with the U.S. mean temperature anomaly over the previous 12 months or T'_{12} ($p=0.01$, $r=0.73$) and the previous 9 months or

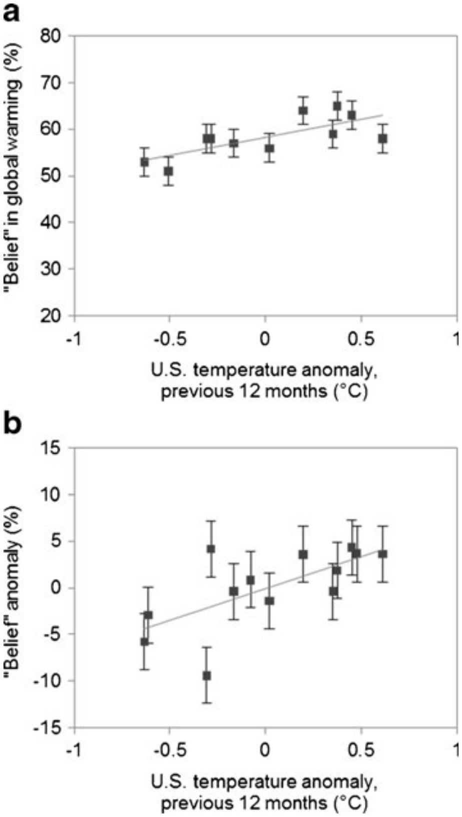

Fig. 1 "Belief" that the planet is warming (in % of respondents) vs. U.S. mean temperature anomaly for the previous 12 months (in °C) using **a** Gallup data, **b** composite poll data. The composite data is presented as annual anomaly, as described in the section 2. A three percentage point margin of error is shown

T'_9 (p=0.08, r=0.54). The T'_{12} relationship equates to a 7.6 percentage point increase in belief in warming for each 1 °C increase in U.S. mean temperature. The significance of this relationship decreases slightly if the trend is removed the temperature anomaly time-series (e.g., p=0.03, r=0.65 for T'_{12}). A similarly significant inverse relationship exists between the fraction of respondents who believe that warming will "not" or will "never" happen and the national temperature anomaly (p=0.02, r=0.73 with T'_{12}). The relationships are weaker but still significant (e.g. p=0.04, r=0.66 for belief that earth is warming and T'_{12}) using only the 2001–2010 data, which eliminates the three-year gap in Gallup polling results after the initial 1997 data point

Using the composite poll data, there is a similar positive relationship (p=0.01, r=0.68) between belief in global warming and T'_{12} . The coefficient of the regression is 6.9 points/°C, within 10 % of the slope of the Gallup relationship. If the Gallup data is excluded from the composite, the significance of the regression decreases (p=0.07) but the slope of the regression only changes marginally to 7.4 points/°C.

With short time series, individual outlier years and correlative variables can have disproportionate influence on the regression. For example, the drop in belief that warming has "already begun" or "will begin soon" in March 2010 polls may reflect the 2009 "Climategate" scandal and the public debate about carbon mitigation legislation, more than the fact that 2009 was the coldest year since 1997. This data point has the strongest influence on the regression; removing 2010 from the analysis reduces the significance substantially in the Gallup case (e.g. p=0.19 for T'_{12}) case but marginally in the composite case (e.g. p=0.03 for T'_{12}).

3.2 Polling question #2: "worry" about global warming

The results are more robust for question #2, for which there are 15 Gallup data points from 1989 to 2010 (Fig. 2). The fraction of Gallup respondents who worry "a great deal" or "a fair amount" about climate change is highly correlated to national temperature anomaly over the previous 3 months (p=0.10, r=0.45) 6 months (p=0.07, r=0.48), 9 months (p=0.03, r=0.56) and 12 months (p<0.01, r=0.72). The relationship with T'_{12} equates to a 9.9 point increase in "worry" for each 1 °C increase in temperature. The relationship between "worry" and U.S. mean temperature anomalies is only marginally affected by removing the trends from the temperature anomaly time series. There is also an inverse relationship between lack of worry ("only a little" or "not at all") in the polling data and the national temperature anomaly (e.g., p<0.02 with T'_{12} since 1989).

With the composite poll data, there was also a significant positive relationship between "worry" (p=0.02, r=0.62, n=13) and the U.S. mean temperature anomaly for the preceding 12 months during the 1997–2010 period. However, this relationship is driven by the more complete Gallup time series; If the Gallup data is removed from the composite, the relationship between "worry" and temperature is not significant (r=0.58, p=0.13, n=8).

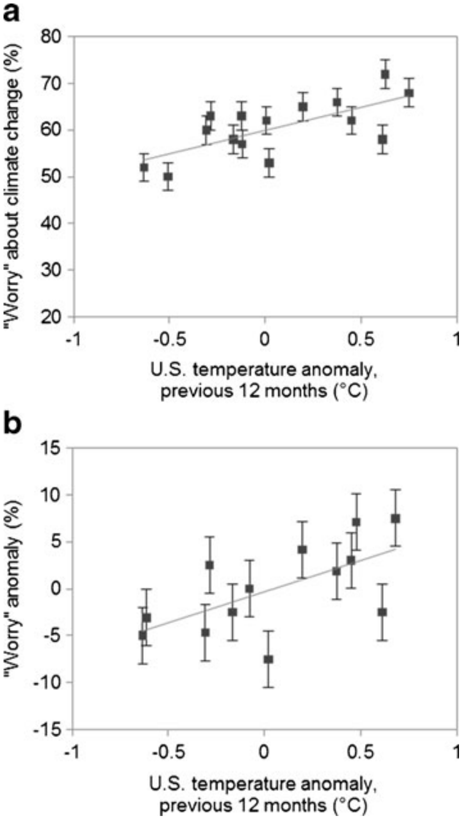

Fig. 2 "Worry" about climate change (in % of respondents) vs. U.S. mean temperature anomaly for the previous 12 months (in °C) using **a** Gallup data, **b** composite poll data. The composite data is presented as annual anomaly, as described in the section 2. A three percentage point margin of error is shown

Individual outliers again have an influence on the regression. If the 2010 data point is removed from either the Gallup or the composite analyses, the relationship with the national temperature anomaly of the previous 12 months remains significant ($p=0.02$ for T'_{12} with Gallup, $p=0.05$ with the composite) and the slope of the relationships changes by less than 4 %. If analysis is further restricted to the 1999–2008 period, the relationship is no longer significant at the 10 % level ($p=0.13$ for T'_{12}).

A rank analysis further illustrates the relationship between temperature and the question #2 responses in the Gallup poll. The highest two poll results for “worry” corresponded with the two highest temperature anomalies $\left(T'_{12}\right)$ during the time series. Conversely, the two lowest poll results corresponded with the two lowest temperature anomalies. If the T'_{12} is ranked according to the poll results, the mean T'_{12} for the highest quartile (in 2000, 1999, 1998 and 2007), middle 50 %, and lowest quartile (1997, 2010, 2004, 1990) of poll results are 0.49 °C, 0.03 °C and −0.30 °C respectively.

3.3 Newspaper opinion articles

From 1990 to 2009, there were 2166 op-ed articles in the five newspapers which expressed an attitude about climate change according to the criteria in this study. The *New York Times* featured the most opinion articles (38 % of the 2166), followed by the *Washington Post* (31 %), the *Wall Street Journal* (16 %), and the *Houston Chronicle* (8 %) and *USA Today* (7 %). The number of opinion articles increased from an average of 55 per year during the 1990–1994 period to an average of 250 per year during the 2005–2009 period, and varied from year-to-year due to events like the release of IPCC reports (2001, 2007), Hurricane Katrina (2005), the relase of *An Inconvenient Truth* (2006) and public controversies like “Climategate” (Fig. 3).

Of the 2166 articles, 66 % were coded as agreeing and 20 % as disagreeing with the expert consensus on climate change. The percent agree was highest in the *New York Times* (86 %) and lowest in the *Wall Street Journal* (17 %). The fraction of the articles agreeing or disagreeing with the scientific consensus varied from year to year, with the lowest percent agree occurring in the years 1993 (54 %, $n=28$) and 2009 (56 %, $n=333$), and highest occurring in the years 2000 (77 %, $n=60$) and 1994 (83 %, $n=12$). From the 1990–1994 period to the 2005–2009 period, the percent agree increased and percent disagree decreased in every newspaper except the *Washington Post*; this change was significant only for the *New York Times* (Table 3).

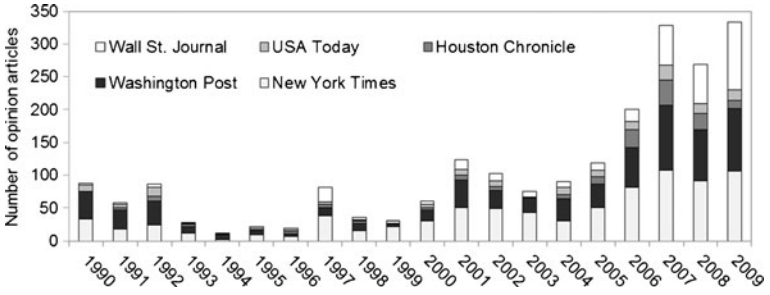

Fig. 3 Number of opinion articles on climate change in the five subject newspapers, 1990–2009. The criteria for article inclusion are described in the section 2

Table 3 Opinion articles from five study newspapers, 1990–2009

	Total	Washington Post	Houston Chronicle	USA Today	Wall St. Journal	New York Times
% Agree						
All years	66 %	66 %	65 %	67 %	17 %	86 %
1990–94	63 %	62 %	56 %	63 %	8 %	74 %
2005–09	66 %	65 %	77 %	71 %	19 %	90 % **
Fall 2008	75 %	82 %	100 %	100 %	27 %	90 %
Fall 2009	50 % **	51 % **	75 %	55 %	19 %	88 %
% Disagree						
All years	20 %	14 %	13 %	19 %	69 %	6 %
1990–94	18 %	13 %	25 %	33 %	77 %	11 %
2005–09	20 %	14 %	5 %	9 %	66 %	3 %
Fall 2008	15 %	6 %	0 %	0 %	64 %	0 %
Fall 2009	34 % **	26 % *	0 %	0 %	68 %	3 %

* $p<0.10$, ** $p<0.05$, *** $p<0.01$(significance of change since previous time period)

There were significant changes in the mean attitudes of individual newspapers in recent years, when opinion writing on climate change was most frequent. For example, after "Climategate" in 2009, there was a significant decrease ($p<0.05$) in the percent agree and a significant increase in the percent disagree in the *Washington Post* and the five-newspaper average; similar changes in the *Wall St. Journal, Houston Chronicle* and *USA Today* were not significant because of the smaller sample size.

3.4 Temperature and newspaper opinion

The percent agree is significantly correlated with national temperature anomaly at the seasonal ($n=80$, $r=0.29$, $p<0.01$) and annual scale ($n=20$, $r=0.26$, $p<0.02$, not shown) from 1990 to 2009 (Table 4). Weaker relationships exist between the opinion articles and the T′ for the Northeast region (Table 4). In the seasonal data, the significance and slope of the relationships differ between the first and second half of the time period in part because of the increase in the article sample size over time. The residuals decrease logarithmically with number of articles in the season ($p<0.01$ for percent agree and disagree), which indicates greater scatter in seasons with fewer articles. If the analysis is restricted to the seasons with ≥10 articles, there remains a significant relationship between T′ and the percent agree ($p<0.05$) as well as a significant inverse relationship between the T′ and percent disagree ($p<0.01$).

The strongest relationship exists between the percent agree (or disagree) and the T′ for the current and previous season (Fig. 4). Including seasons with ≥10 articles, the relationship suggests a 6.6 point increase in the percent agree and a 7.7 point decrease in the percent disagree for every 1 °C increase in temperature (Table 4). Mean T′ for the seasons with the highest and lowest quartiles of percent "disagree" (means of 31 % and 10 %) are −0.17 °C and +0.27 °C respectively; the mean T′ for the second and third quartiles is 0.02 °C. For the percent "agree", there is less separation between two highest quartiles. Mean T′ for the seasons with the highest and lowest quartiles of percent "agree" (means of 79 % and 54 %) are +0.11 °C and −0.17 °C respectively, but the T′ for the second highest quartiles is 0.26 °C.

Table 4 Seasonal analyses of U.S. mean temperature anomaly and codification of opinion articles

By season	% agree		% disagree	
	r	Slope	r	Slope
1990–2009	0.29***	5.3 %	−0.15	−2.5 %
2000–2009	0.21	6.0 %	−0.29*	−3.6 %
1990–1999	0.33**	7.5 %	−0.09	−1.7 %
Winter	0.42*	6.1 %	−0.15	1.5 %
Spring	0.24	6.4 %	−0.32	−7.7 %
Summer	0.42*	8.2 %	−0.46**	−9.9 %
Autumn	0.14	2.3 %	−0.11	−1.5 %
With # of articles >10				
1990–2009	0.29**	4.6 %	−0.35***	−5.1 %
2000–2009	0.14	1.8 %	−0.24	−3.3 %
1990–1999	0.45*	8.5 %	−0.55**	−9.6 %
Winter	0.25	3.0 %	−0.67**	−5.9 %
Spring	0.44*	9.0 %	−0.51**	−11.0 %
Summer	0.26	4.6 %	−0.36	−6.7 %
Autumn	0.24	2.3 %	−0.05	−0.5 %
This season T′ + previous season T′				
1990–2009	0.27**	6.0 %	−0.16	−3.1 %
>10 articles	0.34***	6.6 %	−0.42***	−7.7 %
>10 articles (N.East T′)	0.28**	3.5 %	−0.33**	−3.8 %
2000–2009	0.41***	6.1 %	−0.42***	−6.3 %
1990–1999	0.22	6.4 %	−0.02	−0.4 %
Winter	0.41*	7.5 %	−0.21	2.7 %
Spring	0.16	4.1 %	−0.33	−7.7 %
Summer	0.50**	12.7 %	−0.44**	−12.2 %
Autumn	0.08	1.9 %	−0.13	−2.5 %

* $p<0.10$, ** $p<0.05$, *** $p<0.01$

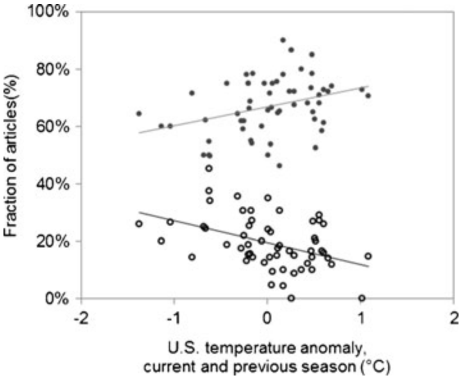

Fig. 4 Percent of opinion classified in "agree" (*closed circles*) and "disagree" (*open circles*) categories by season vs. U.S. mean temperature anomaly for the current and previous season (in °C). Data points represent seasons from 1990 to 2009 in which more than ten opinion articles were published in the five study newspapers

These relationships are driven by the winter, spring and summer seasons (Table 4). For example, the winter T′ explains 45 % of the variance in percent “disagree” during the winter season. Furthermore, analysis of the combined spring and summer T′ and the summer opinion articles indicates a 12–13 point swing ($p<0.05$) in the percent “agree” and “disagree” during the summer season for every 1 °C change in temperature. The only season in which temperature does not influence the opinion articles is the fall (Oct–Dec.), during which political events and other factors are most likely to influence media coverage of climate change.

If the newspapers are examined individually, there are significant relationships between seasonal T′ and opinion only for the *New York Times* and the *Wall St. Journal*. These two newspapers drive the overall relationship between seasonal T′ and opinion, because of their large, consistent sample size and the active editorial stance of the *Wall St. Journal* on climate issues. If the *New York Times* is removed from the all-newspaper computation of percent agree, the significance of the relationship with T′ for the current and previous season decreases slightly ($p<0.01$ to $p=0.04$). If only the *Wall Street Journal* is removed from the analysis, the significance decreases even more ($p=0.16$), even though the *Wall Street Journal* ($n=301$ from 2000 to 2009) contributes less than half the number of articles of the *New York Times* ($n=639$).

4 Discussion

This analysis isolates the possible influence of climate variability on national-scale public opinion about climate change in the U.S. since 1990. In the Gallup data and the secondary data, the polling composite, the U.S. mean temperature anomaly over the previous year explains roughly half the variance in the belief that the climate is warming and whether they “worry” about climate change. Importantly, the U.S. mean temperature anomaly, particularly in winter, spring and summer, is also correlated with the attitudes expressed in opinion articles about climate change published in the prestige press, including newspapers with different editorial positions (the *Wall St. Journal* and the *New York Times*) on the issue. This seasonally-resolved pattern in opinion writing in the U.S. prestige press, which features a longer time series than the polling data, provides additional and more statistically robust evidence for a relationship between climate variability and U.S. opinion about climate change since 1990.

As expected, climate variability only explains some of the variance in public opinion and newspaper opinion writing about climate change. Attitudes about climate change have been linked to a suite of factors beyond weather and climate, including political ideology, party identification, economic variables, gender, age and education, using multivariate logistic regression and more complex statistical models than that employed in this study (Krosnick 2010; Zahran et al. 2006; Brody et al. 2008; Semenza et al. 2008; Joireman et al. 2010; Brulle et al. 2012). Our analysis shows the role of climate variability may be exaggerated due to the concurrence of anomalously warm and cold seasons with other agenda-setting events that may have affected opinion on climate change, including the Kyoto Protocol backlash in cold 1997 and Hurricane Katrina in warm 2005. Declines in public concern about climate change around in the U.S. and around the world in 2009 and 2010 have been attributed to economic factors, “Climategate”, and media fatigue, as well as the anomalously cold U.S weather (Scruggs and Benegal 2012; Ratter et al. 2012). Although longer time series of polling and newspaper data is necessary to clearly distinguish between the influence of climate variability and that of other correlates, our analysis does find significant correlation between climate variability and "worry" about climate change, as well as the attitudes expressed in opinion articles, even with 2009 and 2010 excluded from the analysis.

These correlations between nationally-aggregated weather and opinion data appears to reflect experimental and local evidence that temperature influences attitudes about climate change (e.g. Joireman et al. 2010; Li et al. 2011). They also reflect the evidence that certain weather events or anomalous seasons have driven individual swings in regional or national aggregated public opinion (e.g. Krosnick et al. 2006) and newspaper writing (e.g. Boykoff and Boykoff 2004) about climate change. While Brulle et al. (2012) found that weather did not have a significant aggregate impact on national public opinion about climate change since 2002, that analysis employed a national index of weather extremes rather than mean temperature. This analysis suggests the importance of aggregating weather data into seasonal or annual averages at the regional or national scale, and considering accumulated recent weather experience, not just the weather at a particular point in time.

The limited range of year-to-year variability in the polling data (e.g. 13 percentage points for warming "has already begun" in Gallup Question #1) and the newspaper discourse analysis (e.g. 29 point range in percent agree) suggests that only a fraction of the public holds attitudes about climate change which can be influenced by climate variability or other factors. Recent opinion research suggests that political polarization in the U.S. has created constituencies at opposite ends of the opinion spectrum with hardened views on climate change (Leiserowitz et al. 2010; McCright and Dunlap 2011). Among those segments of the public, additional information or experiences, like an anomalously warm or cold season, reinforces existing attitudes about climate change (Hamilton and Keim 2009; Kahan et al. 2011; McCright and Dunlap 2011). The year-to-year variability presented in this study may therefore be driven by migration of what could be described as climate "swing voters" – members of the public with less defined attitudes about climate change, or with high uncertainty about the available information on climate change (Whitmarsh 2011) – towards the extremes and back.

Climate variability may also influence attitudes indirectly, through its effect on the public discourse about climate change, as reflected in the opinion article analysis. Weber (2006) argues people have a finite 'pool of worry' and manage the amount of attention paid to abstract public concerns like climate change. An unusually warm winter may capture media attention, which in turn leads the issue public, who write opinion articles, and the public at large to think more about climate change. The organized climate 'sceptic' movement, for example, is known to have attempted to influence opinion columnists and to have commissioned timely opinion articles by authors with scientific credentials (McCright and Dunlap 2003; Oreskes and Conway 2010). Furthermore, editors may be more likely to write about climate change or to accept a submission on the subject during or after and anomalously warm season. Therefore, the relationship between climate variability and the opinion data may arise not solely from people viewing weather or climate anomalies as proof or disproof of climate change, but from the anomalies serving as a reminder of the issue of climate change and as "hooks" for opinion articles.

The increasing sophistication of the climate change issue public and their awareness of the cyclical nature of public issues (Ungar 1992) may mitigate some of the influence of weather on opinion. During recent cool seasons, scientists and members of the issue public have proactively written opinion articles about the difference between weather and climate and responding to erroneous claims in the media. For example, a series of claims by *Washington Post* columnist George Will (e.g. Will 2009) about recent climate data prompted editorial responses from members of the issue public (e.g. Mooney 2009), as well as complaints to the newspaper's ombudsman (Alexander 2009). This inverse effect may have reduced the sensitivity of opinion writing in recent years, particularly in newspapers with editorial boards sympathetic to the expert consensus on climate change.

5 Conclusion

The results of this study suggest that the climate variability may be one of the factors driving variability in opinion about climate change in the United States since 1990. When mean temperatures are warmer than normal, the U.S. public tends to be more convinced and more worried about human-caused climate change, and the major agenda-setting newspapers tend to publish more opinion articles expressing either support for the scientific consensus on climate change, concern about climate change, or arguments for climate action. Further research, involving repeat surveys of specific populations, is necessary to clearly distinguish between the role of personal weather experience and other correlates, including other prominent political events and media coverage of weather events.

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References

Alexander A (2009) The heat from a global warming column. *Washington Post*, March 1, p. A13

Antilla L (2005) Climate of scepticism: US newspaper coverage of the science of climate change. Glob Environ Chang 15:338–252

Boykoff MT, Boykoff JM (2004) Balance as bias: global warming and the US Prestige Press. Glob Environ Chang 24:125–136

Brody SD, Zahran S, Vedlitz A, Grover H (2008) Examining the relationship between physical vulnerability and public perceptions of global climate change in the United States. Environ Behav 41:72–95

Brulle RJ, Carmichael J, Jenkins JC (2012) Shifting public opinion on climate change: an empirical assessment of factors influencing concern over climate change in the U.S., 2002–2010. Clim Chang. doi:10.1007/s10584-012-0403-y

Donner SD (2007) Domain of the Gods: an editorial essay. Clim Chang 85:231–236

Donner SD (2011) Making the climate a part of the human world. Bull Am Meteorol Soc 92:1297–1302

Dunlap RE, McCright AM (2008) A widening gap: republican and democratic views on climate change. Environment 50:26–35

Freudenberg WR, Muselli V (2010) Global warming estimates, media expectations, and the asymmetry of scientific challenge. Glob Environ Chang 20:483–491

Hamilton LC, Keim BD (2009) Regional variation in perceptions about climate change. Int J Climatol 29:2348–2352

Joireman J, Truelove H, Duell B (2010) Effect of outdoor temperature, heat primes, and anchoring on belief in global warming. J Environ Psychol 30:358–367

Kahan DM, Jenkins-Smith H, Braman D (2011) Cultural cognition of scientific consensus. J Risk Res 14:147–174

Krosnick JA (2010) The climate majority. *New York Times*. June 9, p. A25 New York Edition

Krosnick JA, Holbrook AL, Lowe L, Visser PS (2006) The origins and consequences of democratic citizens' policy agendas: a study of popular concern about global warming. Clim Chang 77:7–43

Leiserowitz A, Maibach E, Roser-Renouf C (2010) Climate change in the American mind: Americans' global warming beliefs and attitudes in January 2010. Yale Project on Climate Change. Yale University, New Haven

Li Y, Johnson EJ, Zaval L (2011) Local warming: daily temperature change influences belief in global warming. Psychol Sci 22:454–459

Liu X, Vedlitz A, Alston L (2008) Regional news portrayals of global warming and climate change. Environ Sci Policy 11:379–393

Marquart-Pyatt S, Shwom RL, Dietz T, Dunalp RE, Kaplowitz SA, McCright AM, Zahran S (2011) Understanding public opinion on climate change: a call for research. Environment 53:38–42

McCright AM, Dunlap RE (2003) Defeating Kyoto: the conservative movement's impact on U.S. climate change policy. Soc Probl 50:348–373

McCright AM, Dunlap RE (2010) Anti-reflexivity: the American conservative movement's success in undermining climate science and policy. Theor, Culture, Soc 27:100–133

McCright AM, Dunlap RE (2011) The politicization of climate change and polarization in the American public's views of global warming, 2001–2010. Sociol Q 52:155–194

Menne MJ, Williams CN, Palecki MA (2010) On the reliability of the U.S. Surface Temperature Record. J Geophys Res-Atmos 155. doi:10.1029/2009JD013094

Mooney C (2009) Climate change myths and facts. *Washington Post*, March 21, p. A13

Nisbet MC, Meyers R (2007) The polls—trends: twenty years of public opinion about global warming. Public Opin Q 71:444–470

Oreskes N, Conway EM (2010) Merchants of doubt: how a handful of scientists obscured the truth on issues from tobacco smoke to global warming. Bloomsbury Press, New York

Ratter BMW, Philipp KHI, von Storch H (2012) Between hype and decline: recent trends in public perception of climate change. Environ Sci Policy 18:3–8

Russil C, Nyssa Z (2009) The tipping point trend in climate change communication. Glob Environ Chang 19:336–344

Schuldt JP, Konrath SH, Schwarz N (2011) "Global warming" or "climate change"? Whether the planet is warming depends on the question wording. Public Opin Q 75:115–124

Scruggs L, Benegal S (2012) Declining public concern about climate change: can we blame the great recession? Glob Environ Chang 22:505–515

Semenza JC, Hall DE, Wilson DJ, Bontempo BD, Sailor DJ, George LA (2008) Public perception of climate change: voluntary mitigation and barriers to behavior change. Am J Prev Med 35:479–487

Shanahan J, Good J (2000) Heat and hot air: influence of local temperature on journalists' coverage of global warming. Public Underst Sci 9:285–295

Trumbo C (1996) Constructing climate change: claims and frames in US news coverage of an environmental issue. Public Underst Sci 5:269–283

Ungar S (1992) The rise and (relative) decline of global warming as a social problem. Sociol Q 33:483–501

Weber EU (2006) Experience-based and description-based perceptions of long-term risk: why global warming does not scare us (yet). Clim Chang 77:103–120

Whitmarsh L (2011) Scepticism and uncertainty about climate change: dimensions, determinants and change over time. Glob Environ Chang 21(2):690–700

Will GF (2009) Dark green doomsayers. *Washington Post*, February 15, p. B07

Zahran S, Brody SD, Grover H, Vedlitz A (2006) Climate change vulnerability and policy support. Soc Nat Resour 19:771–789

Zehr SC (2000) Public representations of scientific uncertainty about global climate change. Public Underst Sci 9:85–103